BIBLIOGRAPHY

II. CARBOXYHEMOGLOBIN BLOOD LEVELS AND CIGARETTE SMOKING

A. Habitual Smokers

ARTURSON G, GARBY L, ROBERT M and ZAAR B : Changes in carbon monoxide content of whole blood during gas equilibration in the radiometer dissociation curve analyzer (DCA-1). Upsala J Med Sci 77: 22-4, 1972. — Reprint 35

AYERS S M, GIANNELLI S and ARMSTRONG R G : Carboxyhemoglobin: Hemodynamic and respiratory responses to small concentrations. Science 149: 193-4, 1965. — 36

BALBO W, MARUCCI V and RONCHI G U : Les valeurs de l'oxycarbonemie en differentes conditions individuelles et de milieu recherches preliminaires. (Values of blood carbon monoxide under various individual and environmental conditions. Preliminary studies). Acta Med Leg Soc Liege 19: 187-9, 1966. — 37

BARTHE R, PARIS J, DUCHEMIN M and THOMAS F : Valeur et interpretation des taux d' oxycarbonemie obtenus par la methode Nicloux-Endiometrie. Deuxieme note. - Oxycarbonemie et intoxications exogenes: L oxycarbonemie des fumeurs et des ethyliques. Arch Mal Profes Paris 14: 288-90, 1953. — 38

BHOWN A S, MAITRYA B B and HAQ I U : Blood carboxyhemoglobin level in Beedi smokers. Ind J Med Res 57: 1313-5, 1969. — 39

BREWER G J, EATON J W, WEIL J V and GROVER R F : Studies of red cell clycolysis and interactions with carbon monoxide, smoking, and altitude. Adv Exp Med Biol 6: 95-114, 1970. — 40

BREWER G J, EATON J W, GROVER R F and WEIL J V : Cigarette smoking as a cause of hypoxemia in man at altitude. Chest 59: 30S-1S, 1971. — 41

CURPHEY T J, HOOD L P and PERKINS N M : Carboxyhemoglobin in relation to air pollution and smoking. Arch Environ Health 10: 179-85, 1965. — 42

DAHLSTROM H, NORDSTROM-OHRBERG G and ROTHSCHILD A: The influence of tobacco smoking and increased initial carbon monoxide concentration on results of Sjostrand's method of total hemoglobin determination. Acta Physiol Scand 42: 174-84, 1958. — 43

GAENSLER E A, CADIGAN J B, ELLICOTT M F, JONES R H and MARKS A : A new method for rapid precise determination of carbon monoxide in blood. J Lab Clin Med 49: 945-57, 1957. — 44

GETTLER A O and MATTICE M R : The "normal" carbon monoxide content of the blood. JAMA 100: 92-7, 1933. — 45

GOLDSMITH J R, SCHUETTE F and NOVICK L : Appraisal of carbon monoxide exposure from analysis of expired air. Ex Med Int Cong Ser 62: 948-52, 1963. — 46

HANSEN O, WILKE H, MALORNY G and GOTHERT M : Absorption and release of carbon monoxide during breathing of low CO concentrations by smokers and nonsmokers. Chem Abstr 77/6: 43-6, 1972. — 47

HARTRIDE, H:: CO in tobacco smoke. J Physiol London 53: lxxxii-lxxxiii, 1919-1920. — 48

HOFREUTER D H, CATCOTT E J and XINTARAS C : Carboxyhemoglobin in men exposed to carbon monoxide. Arch Environ Health 4: 81-5, 1962. — 49

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McILVAINE P M, NELSON W C and BARTLETT D : Temporal variation of carboxyhemoglobin concentrations. Arch Environ Health 19: 8 -91, 1969. 50

MEIGS J W : Carbon monoxide poisoning. Bull US Army 8: 542-6, 1948. 51

MOTLEY H L : Environmental air pollution effect on pulmonary function. Aerosp Med 42: 1108-10, 1971. 52

PARMEGGIANI L and GILARDI F : Rilievi sulla ossicarbonemia fisiologica. Med Lav 43: 179-83, 1952. 53

ROUCH Y, RIOUFOL F and BOURBON P : Oxycarbonemie spontanee et apres exposition pendant quelques minutes a une atmosphere a un pour mille d'oxyde de carbone chez 43 sujets. (Carbon monoxide content in blood: normal and after a few minute exposure to an atmosphere containing 0, I p. 100 carbon monoxide in 43 subjects). Arch Mal Profes Paris 32: 271-82, 1971. 54

RUEL M H and BARTHE M R : Examen systematique de 132 ouvriers d'usines a gaz avec dosage du CO sanguin. Arch Mal Profes Paris 15: 234-5, 1954. 55

RUHL A and LIN P : Zur frage der Kohlenoxydintoxikation bei starken Rauchern. Deutsch Med Wschr 62: 493-7, 1936. 56

SCHMIDT O : Der gasanalytische nachweis von Kohlenoxyd im Blut, inbesondere bei Rauchern. Klin Wschr 18: 938, 1939. 57

SCHMIDT O : Der Kohlenoxydgehalt des Blutes bei Rauchern. (The CO content of the blood of smokers). Reichs-Gesundhbl 15: 53-8, 1940. 58

SCHRENK H H : Results of laboratory tests. Determination of concentration of carbon monoxide in blood. US Pub Health Bull 278: 36-49, 1942. 59

SIEVERS R F, EDWARDS T I MURRAY A L and SCHRENK H H : Effect of exposure to known concentrations of carbon monoxide. JAMA 118: 585-8, 1942. 60

TRINDER P and HARPER F E : A colorimetric method for the determination of carboxyhaemoglobin over a wide range of concentrations. J Clin Path: 15: 82-4, 1962. 61

VALIC F and DURIC D : Concentration of carbon monoxide in the blood of smokers and non-smokers. Arh Hig Rada (Jugoslav) 5: 49-56, 1954. 62

WEISS E B, SLAWSKY P and DESFORGES J F : Oxyhemoglobin affinity in chronic pulmonary granulomatosis (sarcoidosis) and fibrosis. Am Rev Res Dis 104: 694-702, 1971. 63

WENNESLAND R: Erfaringer fra kulloksyd-gengass-undersokelser hos norske sjafforer og arbeidere. (Experiences from carbon monoxide -producer gas- investigations on Norwegian auto-drivers and workers). Svenska Lakorliden 42: 397-408, 1945. 64

YACOUB M, FAURE J, MALLION J M and CAU J: Peut-on determiner l'origine tabagique de l'oxycarbonisme chronique? (Is it possible to demonstrate chronic carbon monoxide intoxication specifically caused by smoking?). Med Leg Domm Corpor (Paris) 3: 262-5, 1970. 65

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II B. Influence of Smoking on Alveolar Air and Blood Levels of Carboxyhemoglobin

Jongbloed (1939) analyzed the carbon-monoxide content in alveolar air. A trace of carbon monoxide (about 0.0004% or 4 ppm) was detectable in the alveolar air of nonsmokers. In one smoker the content was 10 ppm in the morning before smoking. Then the subject was given 4 cigarettes, each one taking 12 min to smoke with an intervening 12-minute rest period. The results were as follows:

before 1st cigarette	14.0 ppm
after " "	17.9 "
before 2nd "	19.4 "
after " "	23.2 "
after 3rd "	27.1 "
after 4th "	31.5 "
32 min after 4th cigarette	29.0 "
52 min " " "	26.6 "
72 min " " "	23.7 "

There was a progressive increase in the level of carbon monoxide in the alveolar air up to the end of smoking the 4th cigarette. Then a fall occurred in the concentration of carbon monoxide in the alveolar air.

Other investigators have confirmed the observation of Jongbloed. Ringold et al. (1962) analyzed the expired air after a 20-second breath-holding period. The mean ± SD levels of carbon monoxide were as follows:

Nonsmokers (93 subjects)	0.8 ± 4.7 ppm
Heavy smokers (41 subjects)	16.4 ± 12.6 "
Light smokers (25 subjects)	7.7 ± 10.9 "
Pipe or cigar (9 subjects)	3.8 ± 4.9 "

Cohen et al. (1971) reported similar observations and correlated expired air levels of carbon monoxide with blood levels of carboxyhemoglobin.

The results of investigations relating to blood carboxyhemoglobin

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levels are summarized in Table 2. The essential features of the table are:

1. The 11 investigations consisting of measurements of carboxyhemoglobin in blood, resulted in a mean peak level of 5.26% in 29 pooled subjects. The net effect of smoking which was calculated in 15 subjects was an increase of 3.81% of carboxyhemoglobin.

2. There are isolated values as high as 12.3% (Earach et al, 1941), 10% (Ruhl and Lin, 1936) and 6.5% (Whitehead and Worthington, 1961). However, since the control value prior to smoking was not measured, it was not possible to calculate the net effect of smoking.

3. None of the investigations summarized in Table 2 determined the duration of the rise in carboxyhemoglobin. On the basis of work concerning experimental inhalation of carbon monoxide mixture, the duration depends on the concentration of inspired air. There is probably a slow fall in carboxyhemoglobin until the next cigarette is smoked.

After cessation of smoking, a reduction occurs in blood levels of carboxyhemoglobin (Belli and Guiliani, 1955; Ramsey, 1972; Rosenberg, 1968, 1971, 1972). The rate of fall in concentration was accelerated by exercise or muscular effort (Castellino, 1955; Crosetti et al, 1966; Shields, 1971). **1005051083**

Animals have been exposed to cigarette smoke for the investigation of its effect. The blood level of carboxyhemoglobin is elevated in mice (Leuchtenberger et al, 1965), hamsters (Dontenwill et al, 1966, 1967) and rats (Driscoll et al, 1972). In the last-mentioned species, the blood level of carboxyhemoglobin was influenced by the nature of cigarette used. With unfiltered smoke, the rat held its breath, whereas filtered smoke was inhaled with continuation of thoracic respiration.

(Table 2 appears on the next page.)

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Table 2. Acute effects of cigarette smoking on carboxyhemoglobin levels.[1]

Reference (Year)	Number of Cigarettes	No of Subjects	Peak Carboxyhemoglobin blood levels % Mean	(Range)	Δ
Hanson and Hastings (1933)	10-15	6	4.3	(3.1-6.7)	
Ruhl and Lin (1936)	1-2	5		(3.2-10)	
Schmidt (1939, 1940)	1	1			+1.1
	5	2			+1.6; +4
Hsi-Pu and LiMing (1940)	1-5	43	(<5 in 80% of subjects)		
Barach, Eckman and Molomut (1941)	20	18	5.7	(2.2-12.3)	
MacFarland, Roughton, Halperin and Niven (1944)	1	1			+2.0
	3	1			+4.0
Fabre, Truhaut and Berrod (1951)	24	5	4.85		+2.7
Parmeggiani and Gilardi (1952)	2	1			+3
Goldsmith, Terzaghi and Hackney (1963)	12	1			+11.9
Bowden and Woodhall (1964)	2	2			+1.5
Hamill and O'Neill (1969)	20 (cigars)	1			+13
Mean (overall for number of subjects)		5.26 (29 subjects)			+38 (15 subjects)

[1] Some of the values were reported in volumes % and are expressed in this table as saturation % assuming normal hemoglobin values.

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BIBLIOGRAPHY

II. CARBOXYHEMOGLOBIN BLOOD LEVELS AND CIGARETTE SMOKING

B. Influences of Smoking on Alveolar Air and Blood Levels of Carboxyhemoglobin.

Reprint

BARACH A L, ECKMAN M and MOLOMUT N : Modification of resistance to anoxia with especial reference to high altitude flying. Am J Med Sci 202: 336-41, 1941. 66

BELLI R and GUILIANO V : Ricerche sull'ossicarbonismo. Ossicarbonemia da fumo di tobacco e diagnosi di ossicarbonismo cronico. Fol Med (Napoli) 38: 351-8, 1955. 67

BOWDEN C H and WOODHALL W R : The determination and significance of low blood carboxyhaemoglobin levels. Med Sci Law 4: 98-107, 1964. 68

CASTELLINO N : Modifiche della carbossiemia in seguito alla inalazione del fumo di tobacco. Fol Med (Napoli) 38: 1014-24, 1955. 69

COHEN S I, PERKINS N M, URY H K and GOLDSMITH J R : Carbon monoxide uptake in cigarette smoking. Arch Environ Health 22: 55-60, 1971. 70

CROSETTI L, RUBINO G F and PETTINATI L : Osservazioni in tema di detossicazione dell' emoglobina nell'uomo esposto a rischio prolungato da ossido di carbonio. Minerva Med 57: 268-9, 1966. 71.

DONTENWILL W, RECKZEH G and STADLER L : Inhalationsexperimente mit Cigarettenrauch. Beitr Tabakforsch 3: 438-48, 1966. 72

DONTENWILL W, RECKZEH G and STADLER L : Berauchungsapparatur fur Laboratoriumstiere. (Smoking apparatus for laboratory animals). Beitr Tobakforsch 4: 45-9, 1967. 73

DRISCOLL P, DEUBER A, BAETTIG K and GRANDJEAN E : Effect of filtered cigarette smoke on rats. Nature 237: 37-8, 1972. 74

FABRE R, TRUHAUT R and BERROD F : Une nouvelle methode de dosage de l'oxyde de carbone dans le sang. Applications a l'etude de l'oxycarbonemie normale et pathologique. Ann Pharm (France) 9: 625-38, 1951. 75

and HACKNEY J D

GOLDSMITH J R, TERZAGHI J/: Evaluation of fluctuating carbon monoxide exposures. Arch Environ Health 7: 647-63, 1963. 76

HAMILL W and O'NEILL R P : Carbon monoxide intoxication in cigar smokers. Irish J Med Sci 8: 273-7, 1969. 77

HANSON H B and HASTINGS A B : The effect of smoking on the carbon monoxide content of blood. JAMA 100: 1481, 1933. 78

HSI-PU S and Li-MING : Carbon monoxide content of the blood after smoking. J Oriental Med 32: 1135-9, 1940. 79

JONGBLOED J : Uber den Kohlenoxydgehalt der Alveolarluft beim Tabakrauchen. Arch Int Pharmacodyn 63: 346-58, 1939. 80

LEUCHTENBERGER C, LEUCHTENBERGER R and WEISS S : Increase of carbon monoxide (CO) in blood of mice exposed to inhalation of cigarette smoke. Proc Am Ass Canc Res 6: 39, 1965. 81

MacFARLAND R A, ROUGHTON F J W, HALPERIN M H and NIVEN J L : The effects of carbon monoxide and altitude on visual thresholds. J Aviation Med 15: 381- , 1944. 82.

PARMEGGIANI L and GILARDI F : Rilievi sulla ossicarbonemia fisiologia. Med Lav 43; 179-83, 1952. 83

RAMSEY A : Fall in carbon monoxide blood levels after stopping smoking. Lancet I: 755, 1972. 84

100505085

Source: https://www.industrydocuments.ucsf.edu/docs/xfmk0000

RINGOLD A, GOLDSMITH J R, HELWIG H I, FINN R and SCHUETTE F : Estimating recent carbon monoxide exposures. A rapid method. Arch Environ Health 5: 308-18, 1962. 85

ROSENBERG A : Kontrolleret tobakafvaenning. (Controlled tobacco detoxication). Ugeskrift for Laeger 130: 2014, 1968. 86

ROSENBERG A : Synpunkter pa rokavvanjning - erfarenheter fran Kopenhamn. (Viewpoints on smoking withdrawal - Copenhagen experiences. Soc-Med Tidskrifts 2: 108-10, 1971. 87

ROSENBERG A : Fall in carbon monoxide blood levels after stopping smoking. Lancet 1: 593, 1972. 88

RUHL A and LIN P : Zur frage der Kohlenoxydintoxikation bei starken Rauchern. Deutsch Med Wschr 62: 493-7, 1936. 89

SCHMIDT O : Der gasanalytische nachweis von Kohlenoxyd im Blut, inbesondere bein Rauchern. Klin Wschr 18: 938, 1939. 90

SCHMIDT O : Der Kohlenoxydgehalt des Blutes bei Rauchern. (The CO content of the blood of smokers). Reichs-Gesundhbl 15: 53-8, 1940. 91

SHIELDS C E : Elevated carbon monoxide levels from smoking in blood donors. Transfusion 11: 89-93, 1971. 92

WHITEHEAD T P and WORTHINGTON S : The determination of carboxyhaemoglobin. Clin Chim Acta 6: 356-9, 1961. 93

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II C. Passive Smoking

The phenomenon of "passive smoking" refers to the exposure of nonsmokers in an enclosed space containing smoke generated by cigarette smoking. The consequence to the individual in such a situation was first described by Jones et al. (1923), who studied the occupants of a non-ventilated room of approximately 1,000 cu ft capacity, filled with smoke liberated from cigars, cigarettes, stogies or pipe tobacco. The highest concentration of carbon monoxide was 200 ppm and the highest concentration of carboxyhemoglobin in the blood was 5%. Within 15 min, the occupant became uncomfortable and in 45 to 60 min it was necessary for him to wear goggles to prevent eye irritation.

Yaglou (1955) determined the rate of ventilation for a room of 1,410 cu ft, which contained 3 to 4 smokers consuming 24 cigarettes per hr. The passive smokers suffered from headache, watering of the eyes, irritation of the nose and throat, a feeling of depression, and loss of concentration power for reading, when the ventilation was less than 15 cfm per smoker. A ventilation of 25 cfm per smoker was considered as acceptable in preventing these complaints. There were no analyses of blood reported for the subjects. **100505087**

The consequences of passive smoking have been quantitatively measured by Oettel (1967), Markiewicz (1970) and Harke (1970). All three investigators measured the amount of nicotine absorbed by the passive smoker. Only Harke (1970) determined carboxyhemoglobin levels in the blood of active and passive smokers. In a non-ventilated room, 57 cubic meters in size, filled with smoke liberated from 42 cigarettes for 16 to 18 min, the level would reach as high as

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48 ppm. In another room, with a size of 170 cu m, 11 smokers each consumed 9.5 cigarettes within 2 hours. In the presence of a carbon monxoide concentration of 30 ppm, the 11 active smokers had a mean carboxyhemoglobin level of 7.5 ± 0.8% in the blood, while the 7 passive smokers had a level of 3.3 ± 1.4%. With a room concentration of 5 ppm, the respective levels were 5.8 ± 1.6% and 3.3 ± 1.4%; with concentrations of < 5 ppm, the blood levels were respectively 5.0 ± 1.8% and 2.7 ± 1.2%. The effect of exposing the passive smokers to from 5 to 30 ppm caused a net increase of 0.5% in carboxyhemoglobin.

From the above results, Harke (1970) concluded that it is unlikely to find nonsmokers in a room absorbing a significant amount of cigarette smoke. The criticisms by Hess (1971), Schmidt (1971) and Portheine (1971) were largely directed against the measurement of nicotine absorption. The comments regarding carbon monoxide were answered in a rebuttal by Harke (1971), so that the carboxyhemoglobin levels remain valid.

The "passive smoking" situation has been determined by measurement of carbon monoxide in the air. Dublin (1972) reported a concentration of 20.5 to 32.5 ppm in a position next to the smoker in a room ventilated 12.5 times per hour. At the far end of the room the concentration was 13 to 17 ppm. Passive smoking has also been investigated in rats, mice and hamsters (Reckzeh et al, 1969). In these studies, nicotine was also absorbed by the passive smoker.

Harke 71

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BIBLIOGRAPHY

II. CARBOXYHEMOGLOBIN BLOOD LEVELS AND CIGARETTE SMOKING

C. Passive Smoking

DUBLIN W B : Unwilling smoking. California Med 117(1): 76-7, 1972. — Reprint 94

HARKE H P : Zum problem des "Passivrauchens". (On the problem of passive smoking). Munch Med Wschr 112: 2328-34, 1970. — 95

HARKE H P : Zum problem des "Passiv-Rauchens". (The problem of passive smoking). Munch Med Wschr 113: 710-3, 1971. — 100

HESS H : The problem of passive smoking. Remarks on H. P. Harke, Munch Med Wschr 112: 2328-34, 1970. Munch Med Wschr 18: 705-6, 1971. — 101

JONES G W, YANT W P and BERGER L B : Carbon monoxide hazards from tobacco smoke. US Bur Mines Rep Invest 2539: 6, 1923. — 102

MARKIEWICZ K : Bierni palacze. O szkodliwosci biernie wdychanego dymu z papierosow palonych przez innych. (Passive smokers. The harm from passively inhaled smoke of cigarettes smoked by others. Polski Tygodnik Lek 25(52) 2041-2, 1970. — 103

OETTEL H : Erkrankungsrisiko des passiven Rauchens? (Risk of sickness through passive smoking?) Deutsch Med Wschr 92: 2042-3, 1967. — 104

PORTHEINE F : The problems of passive smoking. Comments on H. P. Harke, Munch Med Wschr 112: 2328-34, 1970. Munch Med Wschr 113: 707-9, 1971. — 105

RECKZEH G, RUCKER K, HARKE H P and DONTENWILL W : Untersuchungen zur Bestimmung der akuten und chronischen Toxizitat von Cigarettenrauch bei passiver Berauchung von Versuchstieren. (Studies on determination of acute and chronic toxicity of cigarette smoke in passive smoke inhalation of experimental animals). Arzneimittelforschung 19: 237-41, 1969. — 106

SCHMIDT F : The problem of passive smoking. An opinion about H. P. Harke, Much Med Wschr 112: 2328-34, 1970. Munch Med Wschr 18, 702-5, 1971. — 107

YAGLOU C P : Ventilation requirements for cigarette smoke. Trans Am Soc Heat Air Cond Eng 61: 25-32, 1955. — 108

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II. D. Carbon Monoxide Content of Cigarette Smoke

The presence of carbon monoxide in cigarette smoke and its absorption by the blood were recognized as early as 1899 by Wahl. By shaking a few drops of blood in 2 or 3 mouthfuls of tobacco smoke, he studied the uptake of carbon monoxide from tobacco smoke by the blood of smokers. The presence of carbon monoxide was confirmed by spectroscopy. Wahl concluded that the quantity taken up was insufficient to produce any ill effects. A similar conclusion was arrived at by Lehmann (1908), Culverwell (1915) and Dixon (1927 a and b).

A more direct approach has been to measure the amount of carbon monoxide liberated from cigarette smoke. One gram of tobacco yields a variable amount of carbon monoxide, depending on the method of obtaining the tobacco smoke, the rate of smoking, the closeness of pack and the nature of use, i.e., by cigarette, pipe or cigar. Table 3 summarizes the results of 10 investigations of the amount of carbon monoxide emanating from cigarettes. The mean values range from less than 1 ml to 62 ml of carbon monoxide per gram of tobacco. A convenient median level is 25 ml, which would mean that a cigarette weighing about 1 g, burning in a space of 1 cu m, would result in a concentration of 25 ppm carbon monoxide. In a larger space of 100 cu m, it would require 100 cigarettes to approach a concentration of 25 ppm, or 200 cigarettes one of 50 ppm, assuming that there is no ventilation and that no carbon monoxide is absorbed by the smokers or by the objects inside the room. This calcuation, based on the amount of carbon monoxide liberated from a cigarette, makes it unlikely that enough carbon monoxide can be contained in a room to be a hazard to nonsmoking occupants. Bridge and Corn

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(1972) have arrived at the same conclusion by monitoring carbon monoxide levels in a chamber containing cigarette smoke generated by a machine.

The concentration of carbon monoxide in the cigarette smoke ranges from 2 to 7% (Table 3). As the cigarette was burned and became shorter, the concentration of carbon monoxide was increased (Jarrell and Burde, 1965; Waltz and Hausermann, 1965; Baxter and Hobbs, 1967; Owen and Reynods, 1967; Krusznynski and Henriksen, 1969).

The amount of carbon monoxide in cigarette smoke that is absorbed in the lung has been calculated in a number of ways. Bokhoven and Niessen (1961) measured the concentration of carbon monoxide in the expired air of the same individual with and without inhaling the cigarette smoke. The difference in carbon monoxide concentration in 3 individuals, expressed as % absorbed, averaged 82%. Haebisch (1970) performed a similar analysis and concluded that approximately 7.5 ml of carbon monoxide is absorbed by smoking 45 mm of a cigarette. Dalhamn et al (1968) performed an analysis of smoke administered with a motorized syringe, which drew a 2-second 35 ml puff of smoke, and analyzed the sample before and after the smoke was exhaled by the subject. In 5 subjects, 54 ± 12.7% was retained after deep inhalation, while only 3 ± 0.7% was absorbed when the smoke was kept in the mouth and prevented from reaching the lungs.

(Table 3 appears on the next page.)

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Table 3. Measurement of carbon monoxide liberated from tobacco.

Reference (Year)	ml carbon monoxide/ g tobacco	% carbon monoxide in smoke
Toth (1907)	0.1-0.3	
Marcelet (1907)	20-80	
Lee 1908	4.1	
Lehmann (1909)	15-23.5	
Armstrong (1922)	0.89-1.24	
Baumberger (1923)	8.3	
Ehrismann and Abel (1934)	17.25-35	
Saruta (1937)	62.7	
Kohn-Abrest (1949)	40.0	
Osborne, Adamek and Hobbs (1956)		3.3-5.7%
Philippe and Hobbs (1956)		2.8-5.7%
Stenhagen (1959)	(12-53 mg/cigarette)	
Dumpower, Lewis and Touey (1962)		5.1%
Newsome and Keith (1965)		5-11%
Keith and Tesh (1965)		3.2%
Scassellatti Sforzolini and Savino (1968)		(110 mg/m^3)
Grob (1968)		3.2%
Harke and Drews (1968)		3.4-7.7%
Otsuka, Fujiwara, Ikawa and Hirayama (1970)		3.6%

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BIBLIOGRAPHY

II. CARBOXYHEMOGLOBIN BLOOD LEVELS AND CIGARETTE SMOKING

D. Carbon Monoxide Content of Cigarette Smoke.

ARMSTRONG H E : Carbonic oxide in tobacco smoke. Brit Med J 1: 992-3, 1922. Reprint 109

BAUMBERGER J P : The carbon monoxide content of tobacco smoke and its absorption on inhalation. J Pharm Exp Ther 21: 23-34, 1923a. 110

BAXTER J E and HOBBS M E : Investigation of some physico-chemical aspects of cigarette smoke using oxygen isotopes. I. CO and CO_2 from atmospheric oxidation. Tobacco 164: 26-32, 1967. 111

BOKHOVEN C and NIESSEN H J : Amounts of oxides of nitrogen and carbon monoxide in cigarette smoke, with and without inhalation. Nature 192: 458-9, 1961. 112

BRIDGE D P and CORN M : Contribution to the assessment of exposure of nonsmokers to air pollution from cigarette and cigar smoke in occupied spaces. Environ Res 5: 192-209, 1972. 113

CULVERWELL G H : The toxic possibilities of tobacco smoke. Dublin J Med Sci 139, 241-9, 1915. 114

DALHAMN T, EDFORS M L and RYLANDER R : Retention of cigarette smoke components in human lungs. Arch Environ Health 17: 746-8, 1968. 115

DIXON W E : The tobacco habit. Lancet 2: 881-5, 1927a. 116

DIXON W E : The tobacco habit. Canad Med Ass J 17: 1537-9, 1927b. 117

EHRISMANN O and ABEL G : Uber den Kohlenoxydgehalt des Tabakrauches. Zschr Hyg 116: 4-10, 1934. 118

GROB K : The gas phase of cigarette smoke. Nat Canc Inst Mono 28: 215-20, 1968. 119

HAEBISCH H : Die Zigarette als Kohlenmonoxydquelle. (The cigarette as source of carbon monoxide). Arch Toxikol Germany 26: 251-61, 1970. 120

HARKE H P and DREWS C J : Eine einfache Methode zur Gewinnung gasformiger Tabakrauchbestandteile. Ihre Anwendung zur Bestimmung des Kohlenmonoxide im Rauch. (A simple method for obtaining gaseous constituents of tobacco smoke. Its application for the determination of carbon monoxide in tobacco smoke. Beitr Tabakforsch 4: 275-7, 1968. 121

JARRELL J E : A study of the major gaseous constituents in the mainstream smoke of a cigarette. Tobacco 160: 26-32, 1965. 122

KEITH C H and TESH P G : Measurement of the total smoke issuing from a burning cigarette. Tobacco 160(5): 26-9, 1965. 123

KOHN-ABREST E : Sur l'oxycarbonemie chez les fumeurs. Arch Mal Prof 10: 37- , 1949. 124

KRUSZYNSKI A J and HENRIKSEN A : The quantitative determination of carbon monoxide in tobacco smoke. Beitr Tabakforsch 5(1): 9-11, 1969. 125

LEE W E : The action of tobacco smoke, with special reference to arterial pressure and degeneration. Quar J Exp Physiol London 1: 335-59, 1908. 126

LEHMANN K B : Untersuchungen uber das Tabakrauchen. Munch Med Wschr 55: 723-5, 1908. 127

LEHMANN K B : Chemische und toxikologische Studien uber Tabak, Tabakrauch und das Tabakrauchen. Arch Hyg Munch 68: 319-420, 1909. 128

MARCELET H : Sur le dosage de l'oxide de carbone en particulier dans les fumees de tabac. These Montpellier 32pp. 1902. 129

100505093

Source: https://www.industrydocuments.ucsf.edu/docs/xjmk0000

MUMPOWER R C, LEWIS J S and TOUEY G P : Determination of carbon monoxide in cigarette smoke by gas chromatography. Tobacco Sci 6: 142-5, 1962. 130

NEWSOME J R and KEITH C H : Variation of the gas phase composition within a burning cigarette. Tobacco Sci 9: 65-9, 1965. 131

OSBORNE J S, ADAMEK S and HOBBS M E : Some components of gas phase of cigarette smoke. Anal Chem 28: 211-5, 1956. 132

OTSUKA S, FUJIWARA K, IKAWA H and HIRAYAMA K : Studies on carbon monoxide content in cigarette smoke. J Hyg Chem Japan 16: 150-3, 1970. 133

OWEN W C and REYNOLDS M L : The diffusion of gases through cigarette paper during smoking. Tobacco Sci 164: 28-34, 1967. 134

PHILIPPE R J and HOBBS M E : Some components of the gas phase of cigarette smoke. Anal Chem 28/12: 2002-6, 1956. 135

SARUTA, N : Uber die Quantitative Bestimmung der Kohlenoxydmenge im Tabakrauche. Fuk Acta Med 30: 117-8, 1937. 136

SCASSELLATTI /SFORZOLINI G and SAVINO A : Valutazione di un indice rapido di contaminazione ambientale da fumo di sigaretta, in relazione alla composizione della fase gassosa del fumo. (Evaluation of a rapid index of environmental pollution by cigarette smoke in relation to the composition of the gas phase of the smoke). Riv Ita Ig 28: 43-55, 1968. 137

STENHAGEN E : On the chemistry of tobacco smoke. Acta Soc Med Upsal 64/3-4: 322-40, 1959. 138

TOTH J : Beitrag zur Kohlenoxydbestimmung im Tabakrauche. Chem Zfg 31: 98-9, 1907. 139

WAHL F : Ueber den Gehalt des Tabakruaches and Kohlenoxyd. Pflugers Arch 78: 262-85, 1899. 140

WALTZ P and HAUSERMANN M : Betrachtungen uber die Veranderung des Tabakrauches in der Cigarette. (Refections on the change in tobacco smoke in the cigarette. The yield of crude condensate, total moisture, pyridine nicotine, phenols, pyrocatechol, scopoletin, and carbon monoxide in cigarette smoke as a function of the puff number and of the smoke filter. Beitr Tabakforsch 3(3):169-202, 1965. 141

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III. SOURCES OF CARBON MONOXIDE

The interpretation of the significance of carboxyhemoglobin levels in the blood included the contribution from exogenous carbon monoxide in the atmosphere, as well as endogenous carbon monoxide that is found in the tissues. The details of the contribution of these forms of carbon monoxide are discussed in the articles in additional bibliography list no. 5, dealing with atmospheric carbon monoxide, and additional bibliography list no. 6 on endogenous carbon monoxide. Pollution of the air by factories and by vehicular exhausts are covered respectively in additional bibliography lists nos. 7 and 8. This section will discuss those articles that include analysis of carboxyhemoglobin in the blood of individuals that have been exposed to the sources of carbon monoxide other than cigarette smoking.

A. Carboxyhemoglobin Levels in the Blood of Nonsmokers

It was stated in section II-A that the carboxyhemoglobin contained in the blood of habitual smokers included the contribution from exogenous and endogenous sources of carbon monoxide. Table 4 summarizes the results of 26 investigations of blood levels in nonsmokers. The overall mean for 1,662 subjects was 1.45%. The individual averages varied from 0.4 to 5.2. In cities such as London, Los Angeles and Milan, the residents show the following mean levels of carboxyhemoglobin-respectively: 3.5, 2.3 and 2.8. These values represent a significant contribution from carbon monoxide pollution in the atmosphere.

(Table 4 appears on the next page.)

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Table 4. Carboxyhemoglobin levels in the blood of nonsmokers.[1]

Reference (Year)	Nature of nonsmoker	No of Subjects	Carboxyhemoglobin blood levels % Mean ± SD (Range)
nson and Hastings (1953)	Chicago residents	7	1.5 (1.2-1.9)
Schmidt (1939)	Bonn residents	14	0.6 (0.2-1.1)
Meigs (1948)	US army enlisted men	4	5.2 (0-8.8)
Parmeggiani and Gilardi (1952)	Milan residents	9	2.8 (0-4)
Barthe, Paris, Duchemin and Thomas (1953)	Paris residents	30	(0.6-1.2)
Ruel and Barthe (1954)	Paris residents		0.5
Valic and Duric (1954)	Yugoslavian residents	75	0.9 ± 0.42
Gaensler, Cadigan, Ellicott, Jones and Mark (1957)	Boston residents	9	0.9 (0.6-1.2)
Dahlström, Nordström-Öhrberg and Rothschild (1958)	Stockholm residents	14	0.7 (0.4-0.8)
hitehead and Worthington (1961)	Warwick residents	6	0.8 (0.-1.5)
Trinder and Harper (1962)	Sunderland residents (adults)	23	0.9 ± 0.3 (0.4-2.1)
	(children)	24	0.6 ± 0.2 (0.3-1.0)
Hofreuter, Catcott and Xintaras (1962)	Cincinnati residents	6	1.9
Goldsmith, Schuette and Novick (1963)	San Francisco longshoremen	764	1.3
Goldsmith, Terzaghi and Hackney (1963)	Los Angeles resident	1	2.3
Bowden and Woodall (1964)	Halton residents	42	0.7 ± 0.3 (0.2-1.5)
Curphrey, Hood and Perkins (1965)	Los Angeles longshoremen	115	0.4
Ayres, Giannelli and Armstrong (1965)	New York residents	28	0.9 (0.1-1.9)
lbo, Marucci and Ronchi (1966)	Paris residents	44	1.9 (0-7)
McIlvaine, Nelson and Bartlett (1969)	Durham residents	10	1.6
Lawther and Commins (1970)	London residents	165	3.5

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Table 4. (continued)

Reference (Year)	Nature of nonsmoker	No of Subjects	Carboxyhemoglobin blood levels % Mean ± SD (Range)
Jacoub, Faure, Mallion and Cau (1970)	Paris residents	113	1.5
Rouch, Rioufol and Bourbon (1971)	Toulouse residents	23	1.6 (1.0-3.5
Weiss, Slawsky and Desforges (1971)	Boston residents	13	1.5 ± 0.8
Motley (1971)	Los Angeles residents	115	1.5 (0.2-2.9)
Hansen, Wilke, Malorny and Gothert (1972)	Hamburg residents	37	0.75
Arturson, Garby, Robert and Zaar (1972)	Uppsala residents	11	1.3 (0.9-1.7)
Mean (overall for number of subjects)			1.45 (1662 subjects)

[1] Some of the values were reported in volumes % and are expressed in this table as saturation % assuming normal hemoglobin values.

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BIBLIOGRAPHY

III. SOURCES OF CARBON MONOXIDE

A. Carboxyhemoglobin Levels in the Blood of Non-smokers.

ARTURSON G, GARBY L, ROBERT M and ZAAR B : Changes in carbon monoxide content of whole blood during gas equilibration in the radiometer dissociation curve analyzer (DCA-1). Upsala J Med Sci 77: 22-4, 1972. Reprint 142

AYERS S M, GIANNELLI S and ARMSTRONG R G : Carboxyhemoglobin: Hemodynamic and respiratory responses to small concentrations. Science 149: 193-4, 1965. 143

BALBO W, MARUCCI V and RONCHI G U : Les valeurs de l'oxycarbonemie en differentes conditions individuelles et de milieu Recherches preliminaires. (Values of blood carbon monoxide under various individual and environmental conditions. Preliminary studies). Acta Med Leg Soc Liege 19: 187-9, 1966. 144

BARTHE R, PARIS J, DUCHEMIN M and THOMAS F : Valeur et interpretation des taux d' oxycarbonemie obtenus par la methode Nicloux-Endiometrie. Deuxieme note. - Oxycarbonemie et intoxications exogenes: L'oxycarbonemie des fumeurs et des ethyliques. Arch Mal Profes (Paris) 14: 288-90, 1953. 145

BOWDEN C H and WOODHALL W R : The determination and significance of low blood carboxyhaemoglobin levels. Med Sci Law 4: 98-107, 1964. 146

CURPHEY T J, HOOD L P and PERKINS N M : Carboxyhemoglobin in relation to air pollution and smoking. Arch Environ Health 10: 179-85, 1965. 147

DAHLSTRÖM H, NORDSTRÖM-ÖHRBERG G and ROTHSCHILD A: The influence of tobacco smoking and increased initial carbon monoxide concentration on results of Sjostrand's method of total hemoglobin determination. Acta Physiol Scand 42: 174-84, 1958. 148

GAENSLER E A, CADIGAN J B, ELLICOTT M F, JONES R H and MARKS A : A new method for rapid precise determination of carbon monoxide in blood. J Lab Clin Med 49: 945-57, 1957. 149

GOLDSMITH J R, SCHUETTE F and NOVICK L : Appraisal of carbon monoxide exposure from analysis of expired air. Ex Med Int Cong Ser 62: 948-52, 1963. 150

GOLDSMITH J R, and HACKNEY J D: TERZAGHI J: Evaluation of fluctuating carbon monoxide exposures. Arch Environ Health 7: 647-63, 1963. 151

HANSON H B and HASTINGS A B : The effect of smoking on the carbon monoxide content of blood. JAMA 100: 1481, 1933. 152

HANSEN O, WILKE H, MALORNY G and GOTHERT M : Absorption and release of carbon monoxide during breathing of low CO concentrations by smokers and non-smokers. Chem Abstr 77/6: 43-6, 1972. 153

HOFREUTER D H, CATCOTT E J and XINTARAS C : Carboxyhemoglobin in men exposed to carbon monoxide. Arch Environ Health 4: 81-5, 1962. 154

LAWTHER P J and COMMINS B T : Cigarette smoking and exposure to carbon monoxide. Ann NY Acad Sci 174: 135-47, 1970. 155

McILVAINE P M, NELSON W C and BARTLETT D : Temporal variation of carboxyhemoglobin concentrations. Arch Environ Health 19: 83-91, 1969. 156

MEIGS J W : Carbon monoxide poisoning. Bull US Army 8: 542-6, 1948. 157

2005051098

Source: https://www.industrydocuments.ucsf.edu/docs/xlmk0000

Bibliography III. A

MOTLEY H L : Environmental air pollution. Effect on pulmonary function. Aerospace Med 42: 1108-10, 1971. 158

PARMEGGIANI L and GILARDI F : Rilievi sulla ossicarbonemia fisiologica. Med Lav 43: 179-83, 1952. 159

ROUCH Y, RIOUFOL F and BOURBON P : Oxycaronemie spontanee et apres exposition pendant quelques minutes a une atmosphere a un pour mille d'oxyde de carbone chez 43 sujets. (Carbon monoxide content in blood: normal and after a few minutes exposure to an atmosphere containing 0. Ip. 100 carbon monoxide in 43 subjects). Arch Mal Prof (Paris) 32: 271-82, 1971. 160

RUEL M H and BARTHE M R : Examen systematique de 132 ouvriers d'usines a gaz avec dosage du CO sanguin. Arch Mal Profes Paris 15: 234-5, 1954. 161

SCHMIDT O : Der gasanalytische nachweis von Kohlenoxyd im Blut, inbesondere bei Rauchern. Klin Wschr 18: 938, 1939. 162

TRINDER P and HARPER F E : A colorimetric method for the determination of carboxyhaemoglobin over a wide range of concentrations. J Clin Path 15: 82-4, 1962. 163

VALIC F and DURIC D : Concentration of carbon monoxide in the blood of smokers and non-smokers. Arh Hig Rada (Jugoslavia) 5: 49-56, 1954. 164

WEISS E B, SLAWSKY P and DESFORGES J F : Oxyhemoglobin affinity inchronic pulmonary granulomatosis (sarcoidosis) and fibrosis. Am Rev Res Dis 104: 694-702, 1971. 165

WHITEHEAD T P and WORTHINGTON S : The determination of carboxyhaemoglobin. Clin Chim Acta 6: 356-9. 1961. 166

YACOUB M, FAURE J, MALLION J M and CAU J : Peut-on determiner l'origine tabagique de l'oxycarbonisme chronique? (Is it possible to demonstrate chronic carbon monoxide intoxication specifically caused by smoking? Med Leg Domm Corpor Paris 3: 262-5, 1970. 167

1005051099

Source: https://www.industrydocuments.ucsf.edu/docs/xjmk0000